RESEARCH MANAGEMENT

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ABOUT THIS ISSUE

Included in this issue are three papers presented at the Annual Spring Meeting of the Industrial Research Institute which was held at Buck Hill Falls, Pennsylvania, in May of this year. The first of these is on the currently challenging subject of space exploration; it includes a review of recent accomplishments in space science and an outline of the space program being developed for the nation by the newly formed National Aeronautics and Space Administration. No one could bring this story to us with better insight or more authority than our present author, Dr. Hugh L. Dryden, Deputy Administrator of NASA. Dr. Dryden came to this position with the organization of NASA to include and supersede the National Advisory Committee for Aeronautics; he had been with NACA since 1947 and its Director since 1950. In addition, he had many years of experience in exploratory and applied research at all levels with the National Bureau of Standards. His doctor's degree in physics was received from Johns Hopkins University in 1919.

The second paper discusses some of the problems and prospects faced by the industrial research director today as he encounters increasing competition from government-sponsored research and finds it more and more difficult to obtain increased funds for a broader research program because his company is itself in a profit squeeze. The authors are R. H. Boundy and L. C. Chamberlain, Jr., Vice President and Director of Research, and Assistant to the Vice President and Director of Research, Dow Chemical Company, respectively. Both of them have been with Dow since leaving college. Boundy received his doctor's degree in chemical engineering from Case Institute of Technology in 1930;

Chamberlain received his master's degree, also in chemical engineering, from Tulane University in 1928. Boundy and Chamberlain make two suggestions for increased research efficiency that may appear somewhat radical, namely, the elimination of the pilot-plant, and a major increase in laboratory space available to each professional research worker.

One of the features of the Buck Hill Falls I.R.I. meeting was a rapid fire but meaty talk on the art of listening. The speaker was a specialist in that field, Dr. Ralph G. Nichols, Professor of Speech and Head of the Department of Rhetoric at the University of Minnesota. Our third paper of this issue captures on the printed page as much as possible of the essence of this fascinating talk. Although it does not relate specifically to industrial research, we believe that our readers will find it both interesting and instructive.

Finally, we present a paper by A. G. Ashcroft, a veteran of many years as Director of Research and Development for Alexander Smith and Sons Carpet Company and now Staff Associate with Arthur D. Little, Inc. This paper stresses the intricacy of organization and effort necessary for greatest effectiveness in product growth, discusses the advantages of the product-team approach that is already widely used in technical organization in the research laboratory, and makes the novel suggestion that this project-team idea ought to be applied to top management for more effective cooperation of research, manufacturing, sales, and finance in planning for product growth.

SPACE KNOWLEDGE AND ITS IMPACT ON FUTURE RESEARCH*

HUGH L. DRYDEN
Deputy Administrator
National Aeronautics and Space Administration

Within the past week my associates and I have been discussing with the Congress the proposed expenditure of several hundreds of millions of dollars for the development and launching of satellites and space probes. This is a completely new activity of the human race which has had, in the eighteen months since Sputnik I, a tremendous impact on the intellectual and spiritual outlook of man. The manned and unmanned exploration of space will require and stimulate basic and applied research on the frontiers of knowledge throughout our educational and industrial system. It will have major influence on the development of nearly every branch of engineering and technology.

As a preliminary to discussing the impact of space activities on future research, let us examine the results obtained from the ten earth satellites and the five space probes successfully launched by the U.S.S.R. and the United States since October 4, 1957. New knowledge was obtained about the environment of nearby space, which is not as empty as one might think. Cosmic rays, charged particles, radiations of all wave lengths, electric, magnetic, and gravitational fields, and somewhat fewer meteoric particles and dust than expected are to be found there.

* Presented at the Annual Spring Meeting of the Industrial Research Institute, Buck Hill Falls, Pennsylvania, May 4–6, 1959.

The most dramatic discovery was that of the existence of clouds of charged particles trapped in the magnetic field of the earth which generate radiation when they strike material objects such as a satellite. The first satellite launched by the United States, Explorer I, carried equipment developed by James A. Van Allen, head of the physics department of the University of Iowa, for measurement of cosmic rays. The telemetered data showed a zone of intense radiation in the outer atmosphere. Additional detectors with various sensitivities were used in later satellites and space probes. Results from the space probe, Pioneer III, which traveled to an altitude of 63,580 miles, showed the existence of a second radiation belt. Pioneer IV, which became an artificial planet of the sun, contained devices for measuring the general character of the radiation.

Quite recently, Van Allen summarized the results of his measurements. The inner belt extends from about 1300 to about 3000 miles. The radiation in this belt is very penetrating; little of it was absorbed by a lead shield about one-eighth inch thick. Many physicists believe that the particles in this region arise from the fast decay of neutrons produced by cosmic rays striking the atmosphere. The outer belt extended from about 8,000 to about 33,000 miles, according to the observations made in Pioneer III, but the results from Pioneer IV showed more than twice as many particles in a belt extending from 8,000 to 52,000 miles. Since the latter observations were made after a major disturbance on the sun, it is believed that particles in the outer belt come from the sun. The radiation in this region was almost completely absorbed (99%) by a lead shield about one-eighth inch thick. Beyond the two radiation belts there was no indication of other belts or isolated clouds of charged particles.

Other important contributions to space knowledge have resulted from the satellite programs. Observations on Vanguard I have shown that the earth is slightly pear-shaped, with the "stem" at the North Pole. Simultaneous measurements from islands and mainland have made possible more accurate mapping. Measurements of electron density in the ionosphere show a slow decrease

above the F-2 layer. The density of the upper atmosphere has been found to be higher than expected and variable with position and time with close correlation with solar activity.

This brief and incomplete summary of what we have so far learned is an imposing record of accomplishment. We have greatly increased our knowledge of space. In addition, we have learned much about the shortcomings of our present vehicles which have been assembled from existing pieces of hardware. We have learned much about tracking and telemetering. We have maintained communication with Pioneer IV to a distance of 407,000 miles with apparatus contained in a total weight of 13.4 lb. for both flight and scientific instrumentation, a remarkable demonstration of advanced technology. Solar power has been used successfully for small power levels. Such is the experience from which we go forward to greater achievement.

What are the plans for further research and development in space science and technology? Following the launching of Sputnik I by the U.S.S.R., the United States began to prepare for establishing its role as a leader in space research, space technology, and space exploration. As an interim measure, the Department of Defense was directed to pursue a program of development of satellites and space probes for scientific and military purposes. The launching of Explorer I by the Army Ballistic Missile Agency and the Jet Propulsion Laboratory was accomplished in the record time of four months. The President's Special Assistant for Science and Technology, Dr. James R. Killian, was asked to formulate the objectives of the United States space program and to recommend the governmental organization to achieve these objectives. On April 2, 1958 the President recommended to the Congress the formation of a new civilian agency for which the existing National Advisory Committee for Aeronautics was to be the nucleus agency. It was recommended that military weapons systems and the related research and development remain the responsibility of the Department of Defense. The new agency was to be responsible for space activities concerned with problems of space flight for

peaceful purposes, *i.e.*, scientific studies in space, space technology, and applications of satellites to civil purposes. Specifically, the new agency was to design, develop, and operate space vehicles for research purposes.

In the National Aeronautics and Space Act, which became law on July 29, 1958, we find Section 102(a), which reads as follows: "The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind." The National Aeronautics and Space Administration (NASA) was created to implement this important national policy. It has the additional responsibility of continuing aeronautical research in support of military aircraft and missile development and to extend this support to military spacecraft development.

NASA came into existence on October 1, 1958, beginning the task of establishing comprehensive short- and long-range programs and the organization adequate to carry them out. The initial resources were the nearly 8,000 scientists, engineers, and technical and administrative personnel, and the five major field laboratories of the National Advisory Committee for Aeronautics, whose 43-year existence was thus terminated. The immediate program consisted of a number of projects transferred from the Department of Defense, some of which, such as the original United States scientific earth satellite project, Project Vanguard, brought with them personnel, facilities, and funds.

It was decided that the development and operation of space vehicles would be carried out largely by contract with existing industrial, educational, and governmental groups and that the current development programs would be supplemented by programs of basic and applied research to lay the groundwork for future development. Sufficient in-house effort would be provided to enable adequate technical monitoring of the contract work. Space flight development, aeronautical and space research, and business administration were the principal organizational segments established. In December NASA acquired by transfer from

the Army the functions and facilities of the Jet Propulsion Laboratory, one of the pioneering groups in space exploration. At the same time arrangements were made for the help of the Army Ballistic Missile Agency in carrying out certain projects.

Conforming to the policy expressed in the Act, NASA has established plans and objectives for the application of space science and technology to peaceful purposes. These include the advancement of scientific knowledge of space, the use of earth satellites in meteorology, communications, navigation, and geodetics, and the exploration of space by man.

The term "space science" has wide usage as a shorthand expression for scientific investigations carried out in space through the use of sounding rockets, man-made satellites, and space probes. It is not a scientific discipline in itself. The present program has its roots in the early use of sounding rockets for exploration of the upper atmosphere and in the rocket and satellite program of the International Geophysical Year. With the cooperation of the Space Science Board of the National Academy of Sciences–National Research Council and the National Science Foundation, long-range objectives, as well as a definitive program for the next few years, have been established.

The program is for convenience described in terms of several areas of investigation which are not completely independent. Their interrelations are important aspects of the overall program. The first area is that of study of the atmospheres of the earth, sun, moon, and planets with respect to chemical composition, density, motions, diffusive processes, absorption of solar radiation, etc. The second is that of study of the ionospheres. For the earth, the ionosphere extends from an altitude of roughly fifty to a few hundred miles. It is, of course, the presence of the ionosphere that permits the reflection of radio waves for communication beyond the horizon. The state of the ionosphere is as important to long-range radio communication as is the state of the weather in the lower atmosphere to transportation and other human activities.

A third area of study has already been mentioned, the cosmic

rays in interplanetary space, the great radiation belt of Van Allen, and the auroral particles.

A fourth covers the fascinating subjects of magnetism, electricity, and gravity.

A fifth is that of astronomy. In this field we are planning to establish and operate unmanned astronomical observatories orbiting above the absorbing atmosphere of the earth and to measure with precision the emission and absorption features of the sun, stars, and nebulae in the unexplored ultraviolet, infrared, and x-ray regions of the electromagnetic spectrum. As one scientist remarked, satellites permit observation of the universe in full color compared to the present black and white picture.

The object nearest to us in space is the moon, which is at a distance of about 240,000 miles. NASA's plans and objectives include unmanned lunar exploration as a preliminary to ultimate manned exploration and also the investigation of the surface and interior of the moon and of the nearby space, including atmosphere and ionosphere if the moon exhibits such features. The milestones along this road are the firing of probes to pass close to the moon, already attempted, the establishment of satellites of the moon, the impact of probes on the moon with continuous telemetering of data until impact, and the "soft" landing of instruments which will operate after impact.

The next nearest neighbors of the earth are the planets Venus (about 26 million miles away) and Mars (at a distance of about 49 million miles from the earth). The United States plans include exploratory probes of the space near these planets as soon as our thrust and guidance capabilities permit. At present, the payload capacities are very small so that we have no room for adequate guidance equipment.

Coming now to other applications, there is much promise that earth satellites may revolutionize meteorological research and the observation of weather, resulting, as knowledge and understanding grow, in improved weather forecasting and possibly some degree of weather control. More accurate forecasts have tremendous economic implications for agriculture, food processing

industries, hydroelectric power stations, public utility companies, and numerous other industries. Some studies in a few areas have shown large monetary savings from improved weather forecasts.

At present one attempts to gain a global view of weather from vertical soundings at a limited number of points on the land masses and from a few ships at sea. Satellites properly instrumented make possible world-wide observation of hurricanes, tornadoes, cloud heights and types, precipitation, thunderstorms, temperatures at various levels (from spectral distribution of radiated energy), incoming and reflected solar radiation, etc.

Another early application of earth satellites foreseen is to the development of a world-wide communications system of great capacity, sufficient to include television transmission. The final system might be operated by an industrial group or by a government communications agency as later determined by national policy. NASA's first experiments relate to the use of satellites as passive reflectors of radio waves. It is well known that the moon may be used as a reflector of signals from a very powerful transmitter to a sensitive receiver, provided the geometrical relationships are appropriate. Inflated spheres, 100 ft. in diameter, launched as satellites will provide smaller moons nearer the earth which will require less transmitter power and less expensive equipment. According to a study by John Pierce and others of the Bell Telephone Laboratories,* a passive satellite system may prove economically competitive with ocean cable for transatlantic communication. In addition, the satellite system would make possible wide-band transmission such as television.

I shall not discuss any details of the use of satellites for navigational and geodetic purposes except to say that these applications require satellites of high average density in high-altitude orbits so that the orbit is as regular and predictable as possible and require that the satellite provide optical or electronic transmissions to aid tracking.

Finally, the long-range objectives of the United States pro-

* J. R. Pierce and R. Kompfer, "Transoceanic Communication by Means of Satellites," *Proc. I.R.E.* **47**, No. 3, 372–380, March, 1959.

gram include the exploration of the solar system by man himself. Enroute to this objective are the milestones of orbital flight of man in the simplest vehicle (Project Mercury, much in the public eye recently), in advanced maneuverable vehicles, in larger satellites carrying several men, in permanent manned orbiting space laboratories, in manned flight to the vicinity of the moon and back, and in manned landing on the moon and return.

The objective of Project Mercury is to begin the manned exploration of space by developing the technology needed to place a man in orbit about the earth for a short time and recover him safely and by studying man's physiological and psychological performance. If the orbit is kept at an altitude well below the great radiation belt, no heavy shielding is required. By planning for only a few orbits before recovery, existing life support systems are adequate.

As you know from the public and technical press, the man will travel in a capsule substituted for the nose cone of an intercontinental ballistic missile. He will be supported in a reclining position on a couch for protection against the stress of acceleration on launching and of deceleration on reentry into the atmosphere. The capsule will be provided with equipment to supply oxygen and remove carbon dioxide, with communications and navigation equipment, attitude control jets, and a heat shield to protect from reentry heating, and with a parachute for final landing on water. Reentry will be initiated by the firing of a small rocket to reduce slightly the speed of the capsule in orbit.

The orbiting flight of the first Mercury astronaut will be preceded by extensive tests and qualifications of the capsule and training of the astronaut extending over the next two years. Ballistic flights over short distances, instrumented ballistic and orbital flights, and animal passenger flights are included in this program of testing and evaluation.

The names of the seven Mercury astronauts who will join the project have been announced. These seven men were selected from an original group of 100 military test pilots who met the gen-

eral qualifications. When 80% of the first 69 interviewed volunteered to proceed, the interviews were terminated. The list was then narrowed to 32 persons who were given extensive physical and psychological tests.

The seven astronauts will receive the most intensive course of training ever offered to a party of prospective explorers. Every conceivable characteristic of space flight that can be simulated on the ground or in the air will be made a part of their personal experience. Every detail of the launching, guidance, and tracking procedures will be taught them by ground crews until they know the operation as we know the working of an office in which we have spent the better part of our professional lives. Only one can be first, but there will be several flights in the program.

All this training of the selected pilots and all this repeated testing of the rocket and its component parts are directed toward one end: that the first manned orbital flight of the Mercury vehicle shall be as nearly routine as human ingenuity and practice can make it. We are determined that the risks to the pilot will be no greater than those experienced during the first flights of a new high-performance airplane.

The Mercury project will be followed by others. In due course a permanent, manned satellite will be placed in orbit around the earth; it will serve as a research station and possibly as a station from which to organize deeper penetrations into space. As we master the required technology we shall send an expedition to the moon and, later on, ones to Mars, Venus, and more distant reaches of the solar system.

In order to accomplish these long-range objectives it is essential that we develop rocket boosters and vehicles capable of putting much larger payloads into space. This is the one area in which the U.S.S.R. is definitely ahead. NASA and the Department of Defense have planned a program extending over the next ten years whose goal is to provide the vehicles required for foreseen military and nonmilitary space missions. Time permits only a brief sketch of these developments.

NASA has under development the Vega, a three-stage vehicle having a modified Convair Atlas as a first stage, a second stage incorporating a modified General Electric engine which was used in the first stage of the Vanguard, and a third stage powered by storable propellants developed by the Jet Propulsion Laboratory. The Vega will enable us to put several tons in a 300-mile orbit and to send a 1,000-lb. load to the neighborhood of the moon. It will be available in about 18 months.

Later vehicles in the program are the Centaur, the Saturn, and the Nova. Centaur is similar to Vega, except that the second stage is powered by high-energy propellants (liquid hydrogen and liquid oxygen). The first stage of Saturn is being developed by the Army Ballistic Missile Agency as a cluster of existing rocket engines giving a thrust of more than one million pounds. Nova will be based on a single-chamber rocket of over one million pounds' thrust which is being developed by the Rocketdyne Division of North American Aviation, Inc. under NASA contract.

The Atomic Energy Commission and NASA are jointly developing nuclear rockets for application to space missions as the state of development permits.

Space exploration is at the forefront of the most advanced technology of our time. Underlying it is a pyramid of technology, applied research, and basic research of ever expanding scope. The situation is a dynamic one. As space activities move forward on the foundation of existing knowledge, they reveal the need for and stimulate additional basic and applied research, component development, and advanced systems development. In addition, basic research in what seem to be quite unrelated fields often becomes a dominant factor in further progress.

The current activities in space are in effect an extrapolation of aircraft and missile experience to greater speeds and altitudes. The progress has been, on the whole, evolutionary, except when timely developments in a number of related fields converged to give a steplike change. Thus developments in thermodynamics, aerodynamics, and high-temperature materials converged to make

practical the turbojet engine. This engine had limited utility in the aircraft first available to it, but further developments in high-speed aerodynamics and in new airframe materials and structural designs led to rapid advances in aircraft performance.

The intercontinental ballistic missile was also made possible by the simultaneous maturity of developments in many fields. The chemical rocket is an old device, but only in World War II did it become a practicable propulsion system for large missiles. Our present ICBM's combine large chemical rockets with new developments in structures (pressure stabilized tanks, integrally reinforced skin), inertial guidance systems, light-weight nuclear warheads, and new methods of dealing with the problem of aerodynamic heating on reentry.

As previously indicated, our present space activities are based on rockets and guidance systems developed for the IRBM's and ICBM's; thus, for the next decade or so, the chemical rocket will be the primary propulsion system for space exploration. During this period there will be a continuation of evolutionary growth of basic research in hypersonic aerodynamics and research on new materials based on metals and ceramics which melt at high temperatures, on sophisticated communication and computer techniques, and in many other familiar areas. In each case, the challenge is to gain the knowledge at extreme speeds, temperature, or other adverse environmental condition or to lay the foundation for improved performance.

In the field of fluid mechanics we are entering new regimes of flow in which the older theories become inapplicable. Basic research in these new regimes requires both theoretical investigations and experimentation, the experiments requiring the development of special equipment, often very costly. Under some circumstances, the important aspect of the flow is very low pressure, or, in other terms, a long mean free path of the molecules of the fluid compared to the dimensions of the vehicle. Under other circumstances, the gas is ionized and we have to deal with the flow

of a stream of ions. If both positive and negative ions are present, we have to do with plasma flow. In either case, the flow may be influenced by magnetic and electric fields; if such fields are present, the regime is that of magnetofluid dynamics.

Most of the research so far discussed bears on problems relating to phenomena within the earth's atmosphere as the spacecraft leaves or returns to the earth. There are other areas relating to vehicular problems in outer space. In time, when large orbiting space vehicles become practical, entirely new types of vehicles may be built and assembled in space, and a new technology will arise, unrelated to the extrapolated experience with missiles and aircraft. We can visualize some of these problems now.

In the propulsion field, the low gravitational field in interplanetary space and the great premium on low consumption of propellant lead to great interest in ion or plasma jets accelerated by electrical means. There are many varieties of electrical propulsion systems under study. Their characteristics are very different from those of chemical rockets. An ion-powered vehicle weighing one million pounds may be expected to have a thrust of only one hundred pounds and a propellant consumption of about one-sixth of a pound per second. In a typical system the power source would be a nuclear reactor. The heat from the reactor would be used in a closed-cycle gas-turbine system driving an electrical power generator. This complex system must operate reliably at full power for periods of a year or more, yet the weight should be as small as possible. There are obviously many fields of basic and applied research to be cultivated to insure the success of such a power plant, and it will be some time before reliable engines of this type are available for use.

Space exploration requires a great amount of research and development on energy sources. Chemical batteries and solar cells have been used for limited amounts of power. Fuel cells and several types of small nuclear power sources are under development. The scientific instruments in the payload usually require electric

power. Thus energy-conversion devices are a prime target of research.

Space activities will have an impact on research on man himself and the environment necessary to his life in space. At present we have a legacy of work in connection with high-altitude aircraft and with submarines. We are preoccupied with the physical and psychological stress to which our first astronaut will be subjected. The new environmental condition is weightlessness, whose importance in the long run is now somewhat overrated because of our limited payload capability. In larger vehicles it is readily possible to provide an artificial gravity field by centrifugal force arising from controlled rotation of the vehicle.

The most important long-range problem is that of learning enough about the physiology of man and his needs to develop a closed self-contained system capable of maintaining life for long periods. Only by such means can interplanetary travel be attained.

We have just begun to do research in space environmental chambers of various types. Some surprises have been encountered, although now, with hindsight, we see that we should not have been surprised. For example, because of the extremely low pressure, substances of insufficiently low vapor pressure quickly disappear. Hence materials must be chosen with great care and environmental tests are required. Research of this character is a necessary accompaniment of the development of spacecraft and ultimately will be carried out in orbiting space laboratories. We will want to qualify ion-propulsion systems, for example, by operation in such a laboratory before committing them to journeys of several years.

I have devoted what may seem to be undue space to the impact of space-vehicle development and operation on research connected with the vehicle itself. The most profound impact of space knowledge will be on the basic sciences of astronomy and geophysics, for space vehicles make possible direct experimental measurements in space at the site of the phenomena under study.

Through advance in these sciences we shall gain a deeper understanding of the universe in which we live; our earth and nearby space, the moon and planets, interplanetary space, and distant galaxies. This deeper understanding and knowledge will bring the power to predict, to direct, and to control the forces of Nature and our own destiny. I quote again from the National Aeronautics and Space Act of 1958: ". . .it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind."

PROBLEMS AND PROSPECTS OF INDUSTRIAL RESEARCH*

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Early in the 1850's, a young man not long out of college was dissatisfied with what he found on the banks of the Brandywine. He was Lammont du Pont, a chemist recently graduated from the University of Pennsylvania. He believed that, through chemical research, he could improve explosives and at the same time reduce their cost. With this objective in mind, an old building was converted into a laboratory. Organized industrial research in America originated in this manner. The following century, a mere tick of a watch in the history of the world, has brought tremendous industrial growth from the industrial revolution to date. Paralleling or perhaps preceding this industrial growth has been an equally spectacular growth in research and development. The ten billion dollars spent last year for research and development was larger than the total cumulative expenditure up to 1944. Research, technological innovation, and industrial growth have become a way of life in America. The question, "Why do research?" is no longer asked. It has been replaced with: "How much research can we afford? What is the payoff? What expenditure will maximize profits? What percentage of total

* Presented at the Annual Spring Meeting of the Industrial Research Institute, Buck Hill Falls, Pennsylvania, May 4–6, 1959.

expenditure should be government-supported?" These and many similar questions will be asked with increasing frequency as the cost and volume of research continue to climb. In fact, the cost of research has become so large compared to profits that even the most sympathetic management can no longer be expected to accept on faith an unsupported statement that any given research expenditure is proper for their company. In addition to the fact that most research budgets are now large enough to require careful scrutiny, many industries have been experiencing a "profit squeeze" which has made additional research funds unavailable. Simultaneously, research management has found dangling in its face the enticing bait of government-supported research. This paper considers the probable impact of these forces on research financed by private industry.

Impact of Government Research

Government research has been a part of our economic life for many years, but since 1940 its growth has been phenomenal. It is important to understand this growth and to contemplate its eventual impact on private enterprise.

Perhaps the first recognition by our government of the value of research and invention was in 1790 when the patent system was organized. It has served America well. The founding of the Department of Agriculture and the beginning of land-grant colleges in 1862 was the start of government research as we know it today. The early 1900's saw the beginning of the Bureau of Mines, the National Bureau of Standards, and the multiplication of bureaus within the Department of Agriculture, such as the Bureaus of Chemistry, of Plant Industry, and of Soils. World War I gave rise to the Chemical Warfare Service and the National Advisory Council for Aeronautics. In the 1930's came the National Institute of Health, then the TVA, the Regional Agricultural Research Laboratories, and the National Cancer Institute. With World War II in the offing, the tempo of government involvement in research increased. The Office of Scientific Research and De-

velopment was established, the Manhattan Project began, and finally came our present-day government research in the areas of atomic energy, guided missiles, and the exploration of space. Consideration is being given to the formation of a Department of Science, with a Secretary to have cabinet status. Who knows what more lies ahead?

As late as 1940, the government research budget appears to have accounted for only about 10% of all research expenditures in the United States. World War II sharply increased the rate of government spending for research to about one-half of all research spending in America. Today, in peace time, the U. S. government still pays for about one-half of all research, and the present trend would seem to indicate an even higher proportion in the future. The scope of things considered today to be important to our national health, welfare, and defense is so broad that we find government research money going into every branch of science for both fundamental and applied research.

We in industrial research apparently must look forward to "coexistence" with government research of size equal or greater than ours. Presently, 60% of government-supported research is contracted to private industry and to universities. As time goes by, the government will undoubtedly find reason to conduct an even greater percentage of its work in its own facilities. There are several ways in which industry may react toward government research. We may ignore it; we may seek more research contracts in the belief that some of the effort will be useful to our company; we may choose to operate with only a nucleus of research whose sole function is to seek out and put to use the results of government research; or we may use a combination of methods.

A counterbalance to any advantage to industry from government research is the very real danger that government research will weaken the effective research supported by private enterprise upon which our industrial strength has been based. One of the natural consequences of greatly increased government spending for research may well be the weakening of our patent system.

Patents and Private Enterprise

Patents are granted by our government as incentives to invent and develop new and improved processes and products to be made available to the people of our country. The average patent represents considerable time, effort, and money spent on a unique idea. The grant of a patent gives its owner a chance to recover his costs either by the sale or licensing of his patent or by engaging in business protected by his patent claims.

Industrial research in the United States was established and has developed to its present stature only because those who have provided the financial backing have had the incentive of reasonable patent protection for that part of the output of their research which qualified under United States patent law. The only alternative would be secrecy and a reliance on the laws of the land concerning ownership of know-how. Most companies prefer to rely on the patent system. All agree, incidentally, that the publication which accompanies patenting makes for scientific progress. Certainly, we all agree that companies could *not* afford research if results could not be reserved for each company by patent and civil law.

There are people in our country who are beginning to attach our patent system. They point out that we have anti-monopoly laws on our books which are vigorously supported while, on the other hand, the government is still handing out monopolies through patents. These people would like to completely emasculate the system, greatly reduce the 17-year patent term, or require compulsory licensing. Those who decry the issuing of new patents with their accompanying monopolies have nothing to say about the 40,000 or so patents expiring each year which thereupon become available to the public.

We recently reviewed Dow's approximately 2000 active patents to determine (1) which patents are now being used by Dow, (2) which have been used at some time, and (3) which ones are licensed to others. We found that approximately 20% of our patents were

being actively used and that about 17% of them had at one time been practiced but were no longer in use. Thus about 37% of our active patents have found use in company operations. In addition, approximately 28% of our active patents were licensed to others. All in all, more than half of the 2000 active patents had been used by us or by others.

While disclaiming any expertness in the area of anti-trust theory and practice, we feel that our country's laws are aimed at those who would attempt to control or "corner" essential businesses or services through financial and business juggling, without adding anything to our technology or comfort and yet charging us more for it. The 17-year monopoly conferred with a patent covers an operation or a product which heretofore has been unknown; it interferes not in the least with what has already been available to the public except insofar as it can offer something more attractive. It is a reward for a creative contribution to society. How different this is from the cornering of existing business to the detriment of public welfare! If the critics of the patent system are successful, we may live to see the end of industrial research as we have known it. A combination of factors can do this within our generation. The first factor is the continual growth of government research, and the second is the weakening of the patent system.

Yardstick for Research

Regardless of one's thoughts on patents, fortunately, the best answer to profit squeeze, increasing costs, competition from government research, or any other of industrial research problem is better research. This is a most fortunate and exciting prospect, since doing a continually better job of research is the most interesting thing a research manager has to do.

In order to do better research it seems necessary to have a satisfactory method of measuring the value of research. Why do research on ways of improving research if one cannot measure the improvement? Much has been written on the subject. Some

have reduced the variables to mathematical formula. Probably there is no system satisfactory to all organizations. While we at Dow are far from satisfied and are constantly working toward improvement, we now depend on an annual check list combined with a summation of tangible dollar return. By charting these points so as to show rate of change and by using them with a great deal of judgment, we believe that we arrive at reasonably satisfactory answers to the questions, "How are we doing? How much have we improved?" The following are some of the points we examine critically each year. They are listed in order of increasing time lag.

1. *Research Morale.* It seems reasonable to assume that there is a relationship between morale and research productivity. Even here it is dangerous to jump to conclusions, for our data shows that a "placid pond" is not necessarily conducive to creativity.

2. *Patent Disclosures, Applications, and Patents Issued.* The number of disclosures and the areas they represent, as well as an estimate of the usefulness of issued patents, are to some extent a measure of creativity. The determination of the value of patents from research work is very difficult, especially when the patent is not yet in use. Patents from research work are a fairly good index of the amount of exploratory work going on. When a research organization is exploring new fields, it makes more patentable discoveries than when it is plowing the old established fields of the company. Our company had an unusually fine opportunity to see this phenomenon develop. Immediately following World War II, our business in established products climbed rapidly until our research organization found itself engulfed in problems related to how to make more of everything. During this period, our research expenditures fell to about 2% of our sales dollar. Disclosures of patentable ideas fell off in volume. Then, as we caught up on hiring for our research staff, we saw the output of patentable deas increase out of proportion to the added employees until, at a little over 3% of sales, we had *doubled* the rate of discovery *per*

technical man. To us this meant that we had added enough manpower to take care of the pressing problems connected with present business and enough more to spill over into new fields. We feel that the rate of output of patentable ideas is usually also a barometer of enthusiasm. It is a responsibility of the research administrator to help his company evaluate its patent holdings and exploit them to best advantage.

3. *Scientific Publications.* These serve to indicate that research is being done on a level satisfactory for acceptance by the various scientific societies.

4. *Tangible Values of Process and Product Improvement Research.* These values are reasonably easy to obtain. The time lag is normally only two or three years from the idea to commercial usage. For the purpose of research evaluation, we plot savings from the first year of commercial usage through five years and then drop the item from the list.

5. *Tangible Value of New Application Research.* In this case too, the time lag is usually only two or three years. The same system is used as in evaluation of process and product improvement.

6. *Critical Examination of All New Problems.* Do the problems undertaken during the year cover the proper areas? Are they consistent with company objectives? Are important fields of future growth being neglected?

7. *New Products.* Sales and profits of products which meet our definition of a new product are charted as a fraction of total company sales and profits. Cash flow charts are kept on the important new products. New products are carried on the list for five years and then removed.

8. *Pilot Plant Operations.* Data are kept and charted on new pilot plants, those shut down, the ratio of successes to failures, and the reasons for failure. Data are obtained to chart cash flow if desirable.

9. *Capital for New Plants.* Capital expenditures for the first commercial application of a new product or process as a result of research are reviewed.

10. *Breakdown of Effort.* This is interpreted in four stages: (1) fundamental, exploratory, idea, technical feasibility stage; (2) extensive-data-gathering stage; (3) pilot plant stage; (4) commercial obligation stage.

11. *Royalty Income from Patients vs. Royalty Payments for Patents Licensed from Others.* During our last fiscal year, our company received about two million dollars in royalties for the use of our patents and about $700,000 in return for patents and know-how sold. These are significant amounts of money. It is part of a research administrator's job to see that the returns from past research activities are optimized by buying, selling, or trading research and duplication minimized.

12. *Tangible Research Returns.* Summation of all tangible dollar returns to the company as a result of research done in the past ten years.

Accounting System for Evaluation

Any system of research appraisal must depend on sound accounting which has been consistent over the period of time used for evaluation. Certain information must be obtained to satisfy company requirements for the financial operation of the business. In addition, the same accounting system may be used by research management to obtain additional information desired for the evaluation of research.

The research administrator seeking factual information upon which to base his judgment of efficiency must learn to graft on to his company's accounting system the refinements he needs to measure the variables which he believes will significantly affect research results. If he believes that there is an optimum balance between research on process improvement and on new products, he must be able to measure the amount of each effort. If he believes that exploratory work or applications research are important, he must know how much of each is done. If he believes in some reasonable balance of research among the product and process interests of the

company, he must be able to measure these. If he is to evaluate groups within his organization he must be able to identify man and group with the work done.

In all probability, the research director will need one or two "accounting-wise" people on his own staff who will draw together and monitor the information and convert it into the records, tables, and curves needed for ready reference and confident use. With today's data processing machines available, the reports needed are easily and quickly obtained if the groundwork has been laid through the accounting system and the data is available on cards or tape.

It is wise to recognize that reasonable accuracy at moderate cost is preferable to extreme accuracy at high cost. Accounting records cannot be more accurate than the records turned in by the researcher. His records will be made through his own memory and his own interpretation of definitions. To use accounting methods to pick up every minute and every penny spent is unwise when the records turned in are themselves only approximations.

It is perhaps more important that the records be consistent month to month and year to year than it is that their accuracy be high. Comparison of present results with those of past periods is one of the chief uses to which the data are put. Thus, while the research administrator must be reasonable in his accounting requirements, he must, nevertheless, have a system of records suitable for the evaluation of research progress which he desires or which is required of him. Otherwise, evaluation is futile.

In our own case, we have settled upon accounting based chiefly upon time. Over-all costs of research units are obtained through normal accounting. Within the unit, effort is distributed by hours to the various projects. Projects are assessed by the number of direct hours of effort devoted to them. When costs are desired, these are assigned by determining the average cost of a direct hour of work from the group involved and multiplying by direct hours spent on the project. This avoids trying to assign exact salaries directly to projects; we feel that this is accurate enough for our purposes. We estimate our total cost of accounting

for research to be 1% of our net expenses. Two-thirds of this accounting is necessary for normal company functions. One-third of it has been required for purposes of research administration and evaluation.

Improving Productivity

Having a system for the evaluation of research, even though not a perfect one, makes it possible to initiate changes aimed at improving productivity. There are many approaches which offer the possibility of substantial improvement. The maximum output of any group is the sum of the potentials of all the individuals in the group. How nearly we approach this maximum is controversial. However, it seems completely safe to assume that there remains room for substantial improvement, even in the very best of our research organizations. Since research deals with people and their ideas, effort to improve output must be built around the motivation of individuals and the more effective use of their time. In the routine of our work, it is easy to forget that scientists are human beings and like to be respected as individuals. This must be kept constantly in mind when plans for improvement are formulated. After recognizing that having the right people on the right job is of utmost importance, there are other areas to explore in the quest for better efficiency, some of which are the following.

The Selection of Problems Chosen for Major Effort

This area is mentioned first because it seems to offer by far the greatest potential for improvement. The area is complicated by the fact that if it is not carefully administered one collides head-on with desires for individual freedom. The compromise which seems to offer the most potential is to encourage even more ideas at the exploratory or stage-one level, with a very critical selection of problems for major effort following at later stages. If management accepts the responsibility for keeping the individual researcher com-

pletely informed on company objectives, areas of special interest, and fields of probable extensive future growth, then the responsibility for the choice of problems at stage one can be left largely to the individual researcher. This permits a high degree of freedom at the idea and technical-feasibility stage of research, but as the work progresses toward stage two and the cost becomes increasingly significant, a high degree of intelligent selectivity becomes necessary. At this point the individual laboratory director is in the best position to assist in the choice of problems for the extensive-data-taking stage two. The selection of projects for stage three or the pilot-plant stage is definitely a business decision in which research, production, and sales are involved.

A program of encouraging a very broad base of many ideas with a high degree of freedom at the exploratory level and a planned system of increasingly critical selection of problems as the effort goes up seems to offer a practical balance of freedom, atmosphere for creativity, and control. How skillfully it is administered by research management will determine to a large degree the productivity of the entire research effort.

Communications and Records

Between 10 and 30% of the total research effort is used in literature searching, report writing, recording of data and meetings for communication. These are all essential; nevertheless, a careful study of minimum requirements offers promise of substantial savings with no corresponding loss in effectiveness.

Optimum Space

Since the yearly operating expense of a laboratory approximates the investment in the laboratory facility, one could afford to double the space per man if a 15% increase in efficiency resulted. There is certainly reason to believe that sufficient space to carry on more than one experiment concurrently is desirable. We need to

know more about the relationship of space and productivity. It is probable that a good researcher could use efficiently more than twice the space usually allotted to him.

Instrumentation

Our laboratories should be equipped with the very best tools for doing research. As the cost of manpower increases, it will become increasingly economical to equip our scientists with the very best tools. Present new instruments make information available which could not have been obtained in the past. They also make possible instantaneously available analytical data. We can hope that future instruments will make possible the automation of the entire data-taking stage of research.

The Proper Ratio of Professionals to Technicians

If we are to use our scientists efficiently, they should be relieved of work which can be done equally well by those of lesser training. The best ratio varies for different types of research, but usually we fail on the side of too little nontechnical help.

Transfers from Research

We should encourage a high transfer rate from research to other parts of the company. Research is a young man's business. While good judgment is desirable in research, it is not so essential as it is in production, engineering, sales, etc. To keep the average age of a research group near 35 will require a turnover in the laboratory of 5 to 10% per year. It seems to be a good policy to start most professionals hired by the company in research and then transfer them into production, technical service, etc., as they gain experience and judgment. A scattering of research "alumni" in other parts of the company is an excellent way to improve relations between research and the other functions of the company.

The Scale of Research and Development Studies

The smallest scale feasible should be used; the pilot operation is time-consuming and expensive. Usually, variables can be better determined and engineering data more quickly obtained in the laboratory than in the pilot plant. The pilot unit should confirm the laboratory data and make quantities of material sufficient for sales development studies. The risk of skipping the pilot operation entirely and jumping from bench scale to plant may be justified. The incentive for this is a two-year saving in time and perhaps a million dollars in pilot operation. In any case, the size of the pilot plant should be determined by the quantity of material needed for sales development.

Purchased Research

Where possible, buy research rather than embark on a "me too" program. Frequently, buying research is less expensive and conserves manpower by avoiding duplication. Likewise, one should sell or trade the results of one's own effort where it will not conflict with the company interest. Purchasing research not only results in a shorter time to commercial manufacturing, but also provides a broader product base. In short, buying research makes it possible to take advantage of creative ideas wherever conceived. Research results and technical know-how are becoming articles of world-wide commerce. They may well become very important as self-sufficient trade areas develop, such as the European Common Market.

Use of Research Teams

It is our feeling that research teams can be of extreme value if they are used on projects that have advanced far enough to offer promise of rather rapid solutions, in perhaps six months to one year, by joint efforts. The teams should

be working groups and not merely idea mills. The individuals have ideas that the team can evaluate effectively.

Our concept of the future laboratory is several units of 10 to 20 individuals with different special skills. There would be a central business and administrative organization to work with 10 to 15 units. The teams would thus be more or less permanent and ready to move rapidly on the solution of problems without being saddled with extraneous duties.

Industry Cooperation

Costly duplication of effort could be avoided by industry cooperation. We cannot afford the luxury of so much competition in research. A good example of how industry can cooperate is in the publication of data on the physical and thermodynamic properties of compounds. A liberal policy of licensing each other's patents is a second example.

Motivation of the Scientist

Although recognition is not necessarily a means of increasing productivity, motivation of the scientist and his morale are related to the recognition given him. Examples of recognition are:

1. A simple and understandable salary administration that gives recognition for scientific achievement on the same basis as administrative ability
2. Freedom to pursue research ideas
3. Publications
4. Space and tools
5. "Pat on back for a job well done"
6. Attendance at scientific meetings.

Getting Value From Research

While the product of a research organization is ideas which lead to new products, to new and improved processes, and to prod-

uct improvement, the ideas are worth little if they are not put into profitable use. The aggressive growing company needs research; but also research needs the effective, vitally interested cooperation of every other function of the company if something of value is to come from its effort. Perhaps the key to productive research is to be an integral part of a progressive company willing to take a calculated risk.

In many of the established peacetime businesses, competition has recently narrowed profits about as fast as research has added to them. While research has proven itself worthwhile to the extent now used, we are likely to find it hard to prove that research should increase its effort toward future profits before its past and present work has started the cash to accumulate proportionately.

Summary

The probable impact upon industrial research of both a general profit squeeze and an increasing amount of government supported research has been explored. As we all spend more money and effort on research, it becomes increasingly important to evaluate its progress and results with a minimum of time lag. Research administrators are seeking ways and means to evaluate projects so that only the most profitable are given intensive effort. Also, we seek means of evaluating recent research which has reached developmental or commercial use before complete proof of profitability is established. It is probable that we shall need to become quite knowledgeable of business and economics to do a satisfactory job of accounting for the business value of our work. We also have to help our company optimize the returns from research by seeing to it that patents and know-how are used, licensed, and sold to produce maximum profit.

The tremendous rise in the amount of government research in the last ten years is a very significant factor in the strategy considerations of the modern research administrator. The research administrator is faced with a quandary. To keep his own company's

costs down, he feels that he should sell his services to the government where he can legitimately do so. Yet he must realize that he is building a permanent structure of government research which will make research results and new processes and products available to all on an equal basis. The genuine exhilaration of competitive research among the industries will then be further restricted, and the breadth and depth of government research will make broad patent coverage more and more difficult for industrial research. This prospect makes it paramount that a strong patent system be preserved if our competitive incentive is to continue.

The research administrator is accustomed to change and can and will find in the new challenges of the future the same opportunity for constructive and novel approaches as he did in the climate of the boom 'twenties, the depression 'thirties, and the war 'forties.

THE ART OF LISTENING*

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History of Listening Comprehension Study

In 1940 Dr. Harry Goldstein[1] completed a very important educational research project designed to compare the relative efficiency of reading and listening. From this study, which was underwritten by one of our educational foundations and carried out at Columbia University, there emerged two important conclusions: first, that it is possible for us to listen to speech at a rate more than three times that which we have ever heard before in our lives without any significant loss of comprehension and, secondly, that an important element in our American educational system, that of refining our ability to listen, may have been overlooked.

A few people read this study and were excited by it, but not very many did anything about it. Shortly after that, however, Richard Hubbell,[2] program producer of radio and television programs for the Crosley Corporation, produced a new book in which he declared without equivocation that 98% of all a man learns in his lifetime he learns through his eyes and through his ears.

Hubbell's book threw the spotlight on the importance of the spoken word and prepared us for the results of a study by Dr. Paul Rankin[3] of Ohio State University to determine what propor-

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tion of the waking day is spent in verbal communication. He found that in seven out of every ten of our waking minutes we communicate in one form or another, and that communication time is spent in the following manner: 9% in writing, 16% in reading, 30% in speaking, and 45% in listening.

Quantitatively speaking, America has built her school system upside-down in terms of her emphasis on these communications skills. A youngster may spend sixteen years in school, during which time his teachers try to teach him how to write a sentence in the hope that someday he will be able to write a paragraph and then a report. This involves a sizable expenditure of tax dollars, yet for some reason (inexplicable to me), we stop all reading improvement training at the sixth-grade level. From that time forth, the reading we do is of a voluntary and general character, yet we bewail the fact that the reading ability of many Americans is at fifth- or sixth-grade level. This really should not surprise us, in view of the training we receive.

This is applicable also to training in verbal communication. While speaking comprises 30% of our communication "life," speech training in America remains largely an extracurricular activity. A typical school will produce a play once or twice a year; here may be a small debating team, there, an orator, along with an extempore speaker, and that is about the size of it. There are very few high schools in America in which even one semester of speech training is required. Most of the formal speech training in America today is that given by such schools as those run by Dale Carnegie in night classes at a cost of about $125 per student for enrollment.

Then we come to listening, which comprises 45% of our communication time. In 1948, when I first became intensely interested in this field, hardly anyone had ever thought of the idea of refining his listening ability.

I asked the University of Minnesota for sabbatical leave and spent that year doing research, trying to find out what distinguishes a good listener from a bad listener. I learned initially that nobody

knew much about effective listening. Only one school in America, a girl's college in Missouri, Stevens College, was teaching listening. Only one experimental study in the field of listening comprehension, that of Goldstein, had been published by 1948. By comparison, over 3,000 scientific studies had been published in the field of reading comprehension.

By 1958 a very dramatic change had taken place. Today most of our leading universities are teaching listening and, in addition are doing graduate-level research in the field. Today scores of businesses and industries have instituted listening training programs for selected management personnel.

Several departments of the Federal Government have instituted training programs. A number of units of our military service have started listening training programs. Most important, perhaps, from our point of view, there is a growing conviction that many businessmen talk too much and listen too little in their everyday contact with clients and co-workers.

I would predict that, within another five years or so, no employer of white collar personnel in America is going to sign up a young college or school graduate without first inquiring about his listening efficiency.

Two Central Questions

In view of this tremendous surge of interest in this area in just ten years' time, I should like to discuss two questions; these are:

1. Is inefficient listening a problem in business and industrial management?

2. If so, is there anything that can be done about it?

In order to get a bit of insight on this, I should like to revert to the classroom for just a moment. The first man to produce important evidence on the state of listening comprehension was H. E. Jones,[4] a professor at Columbia University. He was in charge of all the beginning psychology classes there, and he lectured to 476

freshmen. The results of comprehension tests on his lecture content indicated that the students did not understand or retain very much of what he was saying. This suggested to him a plan for a novel experiment. He obtained the cooperation of 50 of his colleagues on the faculty at Columbia, each of whom gave a ten-minute lecture on his own subject matter, submitting an excerpt of his lecture to Jones ahead of time. On the basis of the abstract, Jones developed an objective test on the lecture. Half of the questions demanded a recalling of facts, and the other half required the understanding of some basic principle discussed in the lecture. After each lecture, the group was questioned on its content. On scoring the quiz papers, it was found that the Columbia University freshmen were able to respond correctly to only about 50% of the items in the test. Two months later, he reassembled the 476 freshmen and repeated the tests. This time the students were able to respond correctly to only 25% of the questions. Jones was forced to conclude, reluctantly, that without training, Columbia University freshmen operate at a listening efficiency of only 25%.

I couldn't believe it could be that bad, and decided to repeat the experiment at the University of Minnesota. I did so, but, because I was fairly certain that the recall of lecture material decreases sharply long before two months have elapsed, scheduled the second series of tests for two weeks after presentation of the lectures. I got exactly the same statistics: 50% response in the immediate test situation; 25% after two weeks. Michigan State couldn't believe it; yet, when the test was repeated there, the same statistics were obtained.

Twenty-Five Per Cent Efficiency

I think I can say conservatively and accurately that we listen to a ten-minute talk at 25% efficiency.

Most men are interested in efficiency; many like to talk in terms of 90, 93, 95, or even 98% efficiency in the things they do,

yet, in listening—a thing they do more frequently than almost any other throughout their lives—they operate at about 25% efficiency.

Is this important in business and industrial management? I would like to give you evidence that it is.

Evidence From Industry

A few years ago, a young man discussed with a speech professor at Louisiana State University work leading to a Ph.D. degree in the field of speech. My professorial friend said, "Well, your credentials look good enough; maybe you can take your degree here, but, instead of doing your research in the speech field, I would like you to study the field of listening. I have a project in mind: take a notebook; go to this firm in New Orleans; interview all the management people you can in one week, and ask them the questions I have listed."

When the young man reappeared a week later, he had a notebook full of statements made by management personnel. The gist of these statements was that this was a tremendous organization with a great future and with one of the finest communications systems ever devised in any business or industry.

They said, "Our workers know what we are trying to do; they understand our program," or, "We have the most loyal group of employees to be found anywhere," or "The morale in our outfit is tremendous; the future looks good."

"Okay," replied the speech professor. "Now, put on a pair of coveralls. Go down to that same firm and see Joe Walker, head of the firm's trucking department. Work for him for one year. Carry a notebook in your inside pocket, and whenever you hear the employees say anything about management, write it down in your notebook."

Twelve months later the student returned with a great stack of notes. After studying for several weeks the material which the student had brought back, the professor announced that it was the

most vehement denunciation of one group by another that he had ever read. He concluded that the employees understood less than 25% of what management thought they understood.

I doubted this generalization, and, at a dinner held in Minneapolis one evening, I discussed my skepticism with Erle Savage, the senior partner of the Savage-Lewis Corporation of Minneapolis, an advertising and communications firm. When I told him about this study, he replied, "Don't be so skeptical. As a matter of fact, the picture is even worse than that reported by your friend. My company has just made a very careful study of the communicative efficiency of 100 representative business and industrial managements. If you are interested, I will send you a summary of what we discovered."

He did so, and the situation, as described by that study, is as follows.

Downward Communication

Typically, in the American business world, we have five levels of management, in addition to the employee group. (The number of levels, by the way, seems to be decreasing; only recently several companies have decreased the number of levels of management in their structure.)

If we assume that the top level of management, which we may label the board-of-directors level, understands what they are trying to do—and heaven help us if they don't—then how efficiently is this concept communicated through the levels of management to the other levels?

There is a tremendous decrease in communicative efficiency at the first step down. The vice-president level, which is immediately below the board-of-directors level in most firms, understands 67% of what is relayed to them verbally through normal channels. At the general supervisory level, 56% gets home; only 40% is communicated to the plant manager; 30% to the foreman level; and, in 100 representative American industries

and businesses, only 20%, on the average, of the communication sent downward through five levels of management finally gets to the worker.

Other studies have gone deeper into the question of what the employee who understands only 20% of what his employers think he understands probably thinks about his employer. The 20%-informed individual is usually a negative-minded fellow. He believes that there are big, fat managers up there somewhere at the top who are exploiting him, keeping for themselves most of the profits, and not giving him his rightful share.

His first inclination may be to steal something in order to get even—and the easiest thing to steal in our economy is time. It is pretty easy. You can check in late and pretend you got there early, or leave early and report you left late. If this doesn't satisfy you, you can start stealing tools or equipment. People have been found carrying out a hammer or a saw beneath an overcoat as they walk out at night. One chap was even caught with a nickel roll of toilet tissue under his jacket; he was trying to get even—even a nickel's worth. It is always easy to slow down on the desk or bench or assembly line or wherever you are working. All this is costly business.

Upward Communication

Communicative inefficiency down through the levels of management is a terrible thing, and we are only beginning to appreciate how widespread and wasteful it is. I am much more concerned about the efficiency of upward communication, however, because I feel personally that the efficiency of downward communication will improve significantly only when management better understands the attitudes and opinions of the employee and when the ideas and suggestions of the people at the bottom of the structure can reach those at the top.

The inefficiency of this upward communication was strikingly demonstrated recently in a study of ten factors considered by

researchers to be important to the morale of any employee group.

Management personnel in 24 industrial plants were asked to rank the ten factors in the order of their importance to the morale of the employee group. The researchers went to the employees of these plants also and asked them to rank the same ten factors in the order of importance to them.

The three factors placed by management in the bottom three ranks, at positions eight, nine, and ten, respectively, *i.e.*, "full appreciation of work done"; "feeling 'in' on things"; and "sympathetic help on personal problems," were precisely those ranked by the employees as first, second, and third, respectively.

It is almost incredible that communication is so poor that management would place the three most important factors in the three least important spots, but this kind of evidence emerges again and again when objective studies are made of how well management really understands the attitudes and opinions of the employee group.

Attempts to Improve

Many forward-looking firms in America are aware of this and are making serious attempts to do something about it. A lot of different techniques have been tried. The old one, of course, is to have the boss know everybody. Many a president of many a business takes great pride in the fact that he knows everyone on the payroll; many like to spend half a day, occasionally, walking through the shop or plant and chatting with their employees. This works fairly well as long as the number of employees remains small enough, but it cannot be done in larger businesses. Here different systems have been tried.

We have labor-management meetings in which labor is supposed to "speak out," or we have elected representatives of labor meet with selected management personnel. Neither of these works very well. We have tried hiring a chaplain as a special counselor, with the open invitation to everyone in the whole

organization to go and talk to the chaplain at any time. The chaplain was highly trained in communication and was supposed to feed to top management the important things learned.

Some firms have labor reporters for a house publication; other firms have tried suggestion boxes and complaint boxes, father confessors and mother confessors, opinion surveys and attitude surveys; even though each system has some merit, in every case there is a built-in weakness.

The Central Remedy

I don't have time to expose what seem to me to be the built-in flaws of all these techniques; suffice it to say that they are just devices or techniques. It seems to me they do not get at the heart of the problem, which is sympathetic listening by one man to another.

What I am saying is well set forth in a study recently completed at Loyola University.[6] The researchers spent 18 months trying to determine the attributes of a good manager. They finally arrived at the generalization: "Of all the sources of information a manager has by which he can come to know and size up accurately the personalities of the people in his department, listening to the individual employee is the most important." The description of a good manager that was voiced by worker after worker was, "I like my boss because he listens to me. I can talk to him."

Frank E. Fischer, who is managing director of the American Management Association School of Management in New York City, summarized this in a letter to me a few years ago: "Efficient listening is of such critical importance to industry that, as research and methodology improve, I feel that training departments will have to offer courses in this field." Today, there is a growing awareness of the importance of listening as an attribute of a manager, and such courses are indeed being offered.

I have pursued that first question long enough: "Is in-

efficient listening a problem in business and industrial management?" I hope you will concede that it is.

What Can Be Done?

The second question, "Is there anything that can be done about it?" can be answered in the affirmative. To become better listeners or to make our employees better listeners is a goal perfectly possible to attain.

A few years ago I screened out the 100 worst listeners and the 100 best listeners I could find among the freshmen at the University of Minnesota. These 200 freshmen were then subjected to about twenty different kinds of objective tests. I obtained scores on their reading, writing, speaking, and listening ability, mathematics and science aptitudes, and six different types of personality inventories, and each one filled out a lengthy questionnaire; in addition I had a personal interview with each.

On completion of the study, it seemed to me that ten things clearly differentiated a good listener from a bad one. I published an article reporting "The Ten Worst Listening Habits of the American People."[6] Michigan State University read the article and decided they would repeat the study. They did so, corroboratingly, in large part. A group in Colorado also repeated the study and reported nine of the ten. Because listening training is largely the business of eliminating bad listening habits and replacing them with good habits, I should like to list and comment briefly on what to me seem to be these common bad listening habits.

Ten Bad Listening Habits

1. Calling the Subject Uninteresting

The chairman announces a topic or the bad listener reads it on the program and says to himself, "Gee, how dull can they get, anyhow? You'd think for the money they shell out they could get

a decent speaker on a decent subject. This is such a dull topic that I think I'll worry about that secretary of mine. Am I going to keep her on another year, or am I going to sack her right now?" A lot of us store up such subjects for use in moments of boredom, and this is what the bad listener always does.

The good listener starts at the same point, but comes to a different conclusion. He says, "Gee, that sounds like a dull subject. I don't know what it has to do with me in my business. However, I'm trapped here. I can't get up and walk out. It would be terribly embarrassing and very conspicuous. I guess I may as well tune in this old professor to see if he has anything to say that I can use." The good listener is a sifter, a screener, a winnower of wheat from the chaff, always hunting for something worthwhile or practical that he can store in the back of his mind and put to use at some time in the future. This is a selfish activity, but a very profitable one. We openly acknowledge its selfish character and urge our trainees to become better listeners by hunting for the useful and practical.

G. K. Chesterton put it beautifully many years ago: "In all this world there is no such thing as an uninteresting subject. There are only uninterested people."

2. Criticizing the Delivery

This is something a bad listener does almost every time. The speaker starts to talk, and the man thinks, "Gee, is that the best they can get? This man can't even talk. All he does is try to read from his notes. Hasn't anyone ever told him to look his listeners in the eye when he talks to them? I have never heard a voice as unpleasant as this fellow's. All he does is fidget, snort, and cough. Nobody could get anything from such a character. I'll tune him out and worry about that chemistry test I have to take next week." And off he goes on a mental tangent.

The good listener takes a different position. He says, "I don't know when I have seen such a poor, inept speaker. You'd

think they would get a better man than that for what they pay him. But this guy must know something I don't know, or he wouldn't be up there. Inasmuch as I have paid tuition or a registration fee, I'll dig it out of him if it kills me. I'll concentrate on the message and forget about the lack of smoothness in this character's delivery." After an hour or two of concentrating on content, he forgets about the eccentricities and the oddities of the speaker and begins to get interested in the subject.

Learning and listening are inside action on the part of the listener. The speaker is doing very little of the learning. If learning takes place, it is because of action on the part of the listener.

Suppose a janitor were to appear right now yelling "Get the heck out of here! The building is on fire!" We wouldn't lean back and say, "Please, sir, will you not couch that admonition in better rhetoric?" We would be glad to rush pell-mell out of the building as you know.

The message is ten times as important as the clothing in which it comes. Form has comparatively little to do with the significance of the communication.

3. Getting Overstimulated

I feel like an authority on this, for I have been overstimulated as long as I can remember. I get so excited about people and things that I just can't control myself. I sit there and plot all kinds of things to get in as soon as I possibly can; yet overstimulation is a major factor in listening inefficiency.

A speaker has announced a topic. I am out in the audience, and before he talks three or four minutes he walks roughshod on one of my pet biases or convictions. Immediately I want to raise my hand and challenge him on the spot. If it is too formal an occasion for that, I will sit there and gnash my teeth and figure out the meanest, dirtiest, most embarrassing question I can hurl at him. "Have you stopped beating your mother-in-law yet?" Whether

he says yes or no, he is impaled very nicely. You can use that technique on any topic he is discussing. On occasion I have spent 30 minutes phrasing the most embarrassing question possible for the speaker to answer. If that is not possible, and if I know a little evidence which contradicts something the speaker has said, I will plan a five-minute rebuttal speech.

All too often have I hurled my nasty question or great rebuttal effort at the speaker, only to have him look at me in complete amazement and say, "Nichols, didn't you hear when I went on to say that so-and-so was also true?" I hadn't. My listening efficiency had dropped to zero because I had been overstimulated and excited about making *my* contribution.

We think that this is so important that we put at the top of every blackboard in every classroom where we teach listening back home—and, by the way, we teach 25 per cent of the incoming freshmen on my campus to be better listeners because we don't think they will get through college if they don't—this slogan: "Withhold Evaluation Until Comprehension is Complete." In smaller words we say, "Hear the man out before you judge him." Unless you fully comprehend his point, you are going to make a snap judgment, and at least half the time you are going to guess wrong.

4. Listening Only for Facts

I know that you have great respect for facts. I have, too; but a curious thing exists about these facts. I personally asked the 100 worst listeners I could locate what they concentrated on in a listening situation. Ninety-seven testified proudly that they "listened for the facts." The truth was that they got a few facts, garbled a shocking number, and completely lost the bulk of them.

I asked the 100 best listeners what they concentrated on in a listening situation, and a bit timidly and apologetically they testified in equal proportion, "When we listen we try to get the gist of it—the main idea."

The truth is that these idea listeners got the generalizations or the principles pretty well and they used these principles as connecting threads to give sense and system to the whole talk. Later they were able to append more facts to these connecting threads than the bad listeners were able to catalogue and report.

We had to conclude that if you want to be a good listener you should try to get the gist of the discourse—the main thread, the idea, the principle, the concept, the generalization. Facts can be retained only when they make sense, and they make sense only when they support a generalization of some kind.

5. Outlining Everything

This is a curious business. We found that the 100 worst listeners thought that note-taking and outlining were synonyms. They knew no way to take notes other than to make an outline of the speech. There is nothing wrong with outlining if the speaker is following an outline pattern of organization.

However, unfortunately, between today and the day you die probably not one-third of the speakers you hear are going to present discourses carefully organized on an outline pattern or scheme—and one of the most frustrating things in this world is to try to outline the un-outlinable.

The student who does it always comes out with a sheet of notebook paper that is a perfect and beautiful thing in terms of symmetry—all the margins and indentations perfectly ordered, the symbols all nicely subordinated, and there is meaningless jargon after each symbol. Two months later, when he tries to review his notes, they have no meaning whatsoever.

We asked the 100 best listeners how they organized their note-taking, and they said, "It all depends on the speakers. We listen for a while and do nothing. When we figure out whether or not he is organized, we sometimes write little abstracts. We listen three or four minutes and write a one-sentence summary of what has been said. Sometimes we use the fact-versus-principle technique.

I am fascinated by this last technique, for I feel it is highly effective. The student has two sheets of notebook paper side by side when he goes in to hear a lecture. At the top of one sheet is written the word "facts," and at the top of the opposite sheet is written the word "principles." The student lists in vertical columns the facts or principles presented. The system calls for a minimum of writing and provides the best notes you can possibly have for purposes of review.

Our conclusion was that the good listener is flexible and selects from many systems of taking notes the best one for recording what is said by any particular speaker.

6. Faking Attention

As a schoolteacher, for many years I felt I was going over big if I looked over the classroom and saw the bulk of my students with their chins in their hands. I was always pleased to see the girls in the first rows looking like that. I thought they were listening to me.

We now know that the surest index to inattention in all this world is this posture on the part of the listener. Having paid the speaker the overt courtesy of appearing to be attentive, the listener feels free to take off on a thousand different mental tangents.

If you ever face an audience and, looking out across the room, see the bulk of your listeners in this pose, stop short in your talk and tell them to stand up and do calisthenics to get their blood circulating again.

Efficient listening is characterized by a quicker action of the heart, a faster circulation of blood, and a small rise in body temperature. It is energy-consuming; it is dynamic and constructive.

The best meaning of the word "attention" is a collection of tensions inside the listener—tensions that can be resolved only by getting facts and ideas the speaker is trying to convey. If we would listen well, we will have to expend some energy in the process.

7. *Tolerating Distraction*

Bad listening habit number seven is tolerating or creating distractions. I do not believe it is necessary to elaborate on it.

8. *Evading the Difficult*

We asked our 100 worst listeners what they listened to on radio and television. We found that these 100 worst listeners were authorities on Bob Hope, Red Skelton, and *The Lone Ranger.* Apparently they had spent their lives listening to these programs.

Not one of those bad listeners had ever sat clear through the *Chicago Round Table, Town Meeting of the Air, Meet the Press, Invitation to Learning, See it Now,* or *You Are There.*

We asked the 100 best listeners, and they knew all about Bob Hope and Red Skelton, to be sure; but, voluntarily or otherwise, they often sat through some of the more difficult technical and educational programs on radio and television.

We finally concluded that the one word in the dictionary that best describes the bad listener is the word "inexperienced." While it is true that he spends 45% of his communication day listening to something, that something is always recreational or narrative in character. He avoids anything more difficult, technical or expository in character.

Take a youngster who has never heard anything more difficult than Bob Hope and put him in an auditorium, with 300 other freshmen, to hear a lecture by a professor of biochemistry. The boy says, "Gee, what am I doin' here? What's he talkin' about?" He cancels that course and enrolls in another, say, economics. He finds this just as hard. Within three months he washes out of school and is gone.

Of every two freshmen who come to our university and college campuses in America today, one fails before the end of his sophomore year—most of them before the end of the freshman year.

On the other hand, in most instances, for every graduate who earns a four-year degree there are two employers waiting to bid

for his services. Fifty per cent mortality on the intake! And we meet half of the demand on the outgo! This situation is critical. I am not sure how long we can compete in the modern world if we continue to suffer loss of trained manpower. If I could have my way about it, I would require every schoolteacher in America, at every grade level, in every subject being taught, to teach ten minutes of listening every week.

I would ask her to announce the plan on Monday, and on Friday I would ask her to present ten minutes of the most technical expository material that the class had ever heard in their lives up to that time. Immediately following this ten-minute presentation, which might be taped, recorded, or given face to face, I would ask her to give a comprehensive test on its content.

I would like the teacher to put the score earned by each student at the front of the room on a bulletin board or blackboard, to reveal week by week how his listening performance is improving.

I have said this to teachers' groups, and they say, "I teach physics," or, "I am the coach. I can't spend time on that kind of stuff."

Then I say, "Wait a minute! Ninety-eight per cent of what a man learns he learns through his eyes or ears, and almost always this is by reading or listening. In the education field learning is everybody's business, and we ought to be able to spend ten minutes a week on improving this tremendous learning medium of listening."

I feel that if we could get a little training, grade by grade, ten minutes a week, in listening to technical material, we could decrease the mortality at the college level considerably. America needs more educated men and women to improve her economy and to improve her culture.

9. Submitting to Emotional Words

A single word may have such an emotional load in it that it throws some listener or group of listeners out of tune with the

speaker. We know that the word "mother-in-law" sometimes does it; the word "evolution" does it to others; "automation" and "big business" are also potential troublemakers.

Last year I learned that department store personnel do not want to be called "clerks." Unfortunately I had used the word "clerks" in a talk, and I had five women reproach me afterwards. If you ever try to sell insurance to an employee of a department store, call her one of the "retail sales personnel" and you will do much better. Such terms as "income tax," "landlord," "nigger," "Harry Truman," and "Sherman Adams" are all fighting words that tend to disrupt listening efficiency for some people at some time or other.

I feel this is very important. A very important study, I think, would be for some graduate student to identify the 100 greatest word barriers to learning. I wish I knew what they were. If we knew what 100 words cause most of our difficulty as barriers to communication, we could consider them one by one, bring them out into the open, discuss them, rationalize them, and get them behind us.

It is silly to let a simple word—merely a symbol of something—get us so excited as to disrupt our listening efficiency; yet we do this all the time.

10. Wasting Thought Power

Bad listening habit number ten I have left until last because I think it is by far the most important of all. It is wasting the differential between thought speed and speech speed.

On the average, we talk 125 words per minute in conversation. If you are in front of an audience and are speaking more or less formally, you slow down. On the average we talk 100 words per minute when we speak informatively to an audience. On the other hand, you will never face an audience of any size that does not, on the average, think at an easy cruising speed of at least 400 to 500 words per minute. The difference between speech

speed and thought speed operates as a breeder of false security and a breeder of mental tangents. It operates as a tremendous handicap to a member of the audience as he tries to stay with the speaker. He thinks circles around what the speaker is saying and may conclude that it is all "old hat." If so, he tears off on some problem that intrudes itself upon his mind and after 50 seconds or so checks back on the speaker again. Once more he decides that what the speaker is saying is without value and off he goes for another 50 seconds on another mental tangent. This is the pattern followed by many listeners.

This is why we listen at an average efficiency of 25%. It is because of the constant allurement of mental tangents. It seems to be almost impossible to keep our minds free from them.

What is the answer? It is obvious. If you can think five times faster than a man can talk to you, this should be a source of power; it should not be a weakness. As it operates without training it is a liability, but with training it can be converted into a tremendous asset. This is the most precious possession we own—the ability to think so rapidly. The process of conversion is merely the business of learning what things to engage in mentally in order to stay tuned in on the speech.

Mental Manipulations

These activities, these mental manipulations, are three in number. Wherever you find listening training succeeding today, you will find them in the training program.

1. Anticipate Speaker's Next Comment

In order to increase concentration, anticipate what the speaker is going to say next. One of the best things you can do is to dash ahead of him (mentally) and try to guess what his next main point is likely to be. If you guess it is going to be point A and it turns out to be point A, learning is reinforced, nearly doubled,

for that point came twice into your brain centers instead of once. If you guess it is going to be Z and it turns out to be A, you begin to compare Z with A, and wonder why the speaker didn't make Z his next point. When you compare the point you thought the speaker was going to make with the one he did make, you are, without knowing it, applying the oldest law of learning in the books—that we learn best by comparison and contrast. It is the one wager you can make in life which you cannot lose. Whenever you listen, dash ahead mentally and try to guess what the next main thought is likely to be. If you guess wrong you still win. And always you are kept from dragging along behind the speaker, taking notes on something he said three minutes earlier.

2. Identify Elements

Mental ingredient number two in concentration is to identify the supporting elements the speaker uses in building his points. By and large, we use only three ways to build points. We explain the point, or we get emotional and harangue the point, or we illustrate the point with a concrete example following the generalization. The sophisticated listener knows this. He spends a little of the differential between thought speed and speech speed in identifying what is being used as point-support material. This yields great profit in terms of listening efficiency.

3. Make Mental Summaries

Finally, and most important, the good listener throws in periodic mental summaries as he listens. At the end of about three or four minutes, if the speaker draws a long breath or walks around the lectern or takes a swallow of water, or if there is any pause at all, the sharp listener dashes clear back to the beginning of the discourse and makes a quick mental summary of what has been said up to the point of the break. We call these "dashes" mental recapitulations. There ought to be a dozen or more in every

lengthy talk we hear. They are the greatest dividend-payer in listening efficiency that we can possibly master and practice.

These periodic summaries as we listen are tremendous reinforcements of learning, and the beautiful thing about it is that we use to our own profit the ever-present differential between thought speed and speech speed.

Conclusion

All of the above has been summarized by the greatest Teacher who ever lived, Christ Himself, who said (Mark, 4: 23–24) to the audience before Him: "If any man have ears to hear, let him hear. Take heed what ye hear; with what measure ye mete, it shall be measured to you: and unto you who hear shall more be given."

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THE INDUSTRIAL PROBLEM OF PRODUCT GROWTH. THE PROJECT TEAM APPROACH*

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We have come to accept, almost without question, that the industrial progress indicated in the General Electric slogan, "Progress is our most important Product," as well as our *national* progress is measured by and identified with *product change*. Whether we are thinking of a new synthetic fiber to give us clothing for minimum care, a new ceramic for effortless transfer from refrigerator to oven to table, atomic power plants, or a new rocket to put a satellite into orbit and extend our television coverage, our image of progress has become associated almost solely with our industrial product growth. We are in a period of change at such a rapid rate that the new product of today may be replaced within weeks by an improved one resulting from developments in often unrelated technical and industrial fields.

For example, a large paper-products manufacturer affects both the chemicals and textiles fields by introducing a urethane foam product with the cellular structure broken down so that a foam material of 1/8-inch thickness has the drape and handle of a thin textile fabric and conceivably could be used in apparel as a

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lining and insulator. A carpet manufacturer crimps wool and filament nylon, and the Banlon filament crimping process affects the knitting trades at the rate of 20 million pounds a year. A manufacturer of men's shirts invents a compacting process for kraft paper and a new company is organized to license the production of resilient paper of high impact strength. A textile manufacturer develops a system of joining hundreds of small nylon monofilament hooks to a similar number of fabric eyelets and a new fabric joiner competing with hooks and eyes, buttons, and zippers enters the market. Similar instances can be noted daily.

Some may question as to whether product change at so rapid a rate is really progress or is economic. Those industries which have failed to provide for product growth in their own field or in new areas have suffered the devastating blows of product obsolescence at a rate higher than in former generations. Unfortunately for those who do not pay the insurance of research and development and do not plan for rapid product change, this accelerating rate of competitive flow cannot be turned off. The old saying that "you must run fast to stay in place" has and will continue to become the epitaph of many a formerly prosperous company.

The control over this rate of change is in the hands of the consumer. He determines by an exchange of his earnings for the new product whether or not new values have been created for him or his family. Savings offered the consumer in time, labor, or expense will earn his approval. He will also support products which give aesthetic satisfactions.

Dynamics of Product Growth

In Chart I, an effort has been made to describe in graphic form the dynamics of the problem of initiating industrial product growth. In this chart the consumer is the target or focal point of the two basic questions around which product growth orbits.

1. *How* to find out what it *is* that is *wantable?*
2. How to tell what it is that meets the want?

CHART I

The Dynamics of Industrial Growth

People	Areas of knowledge Things	Words
Economics	Biology	Advertising
Journalism	Chemistry	Certification
Law	Mathematics	Merchandising
Psychology	Physics	Marketing
Political Science	Mechanics	Public Relations
Industrial Management	Engineering	Industrial Relations
Research Administration	Design	Standardization
Sociology	Medicine	Selling

Areas of interaction		
Societies and associations		Consulting groups
Management	Industrial Laboratories	Commercial Laboratories
Consumer	Plant Engineering and Design	Research and Development
Trade	Production and Marketing	Engineering
Standards	Universities	Management
Engineering	Government Research	
Scientific	Research Institutes	

How to find out what it is that is wantable

THE CONSUMER TARGET

How to describe the way products meet consumer wants

It is not difficult to generalize on broad areas of wants of the consumer. It is well known, for example, that we no longer can have economic domestic help. The homemaker is eager to acquire products which reduce the work of washing dishes, cleaning floors, and ironing shirts. It is not so easy, however, to define the

specific want that decides purchase when the attributes are a combination of competing values, particularly when these include relative cost, style, and other aesthetic values. Such a mixture of attributes makes it equally difficult to describe to what degree the product *meets* the wants and precisely *how* the improvements will be more wantable and give greater satisfaction.

It may be assumed that identifying the products or services wanted and new ideas for creating, developing, and producing products will stem from creative individuals using some combinations of areas of knowledge. Often individuals skilled in the technologies of human behavior or those in advertising or sales may make a contribution greater than those in the area of science in helping to answer the questions—What it is that is wantable? and How to describe what it is that meets the need? Historically, however, science and engineering stimulated by each new scientific breakthrough has been the largest factor in finding new ways to answer the physical aspects of human wants. Research and development in industry, stimulated by competition and the profit motive, has made our progress in creating new products and services the marvel of this century.

The industrial laboratory is the physical form of an organized and directed effort to create new products. The laboratory is the investment of industry in a method of providing itself with the technology it needs for its present and long-range product growth. In such a facility, a skilled scientific staff generates the necessary interactions with the other elements of the research mechanism. The research and development activity, therefore, should be recognized by the management of a company as the *nucleus* of a complex mechanism for growth. A properly organized R & D facility can cultivate and stimulate the necessary interaction between the various skills within the company. It can use scientific and engineering knowledge as a protagonist of change aimed at the creation, development, and introduction of new products into commerce. It should be, therefore, the *catalyst* of a continuing and dynamic function of product growth.

The voluminous literature describing the organization and management of the R & D function often seems to suggest that the *process* of creating or evolving major product changes and the carrying forward of new product to large-scale output is operable solely *within* the parameters of a formal R & D function and organization. We know this is not true. However, this concept has been nurtured by the idea, often expressed in the literature, that the choice of projects for research and the selection of products for commercialization occur only in the laboratory with the advice of staff executives at infrequent intervals.

We know that such a concept is a poor answer to the complex problem of planning an effective technique for product growth. Management cannot release its responsibilities for corporate-growth planning to R & D, nor can R & D assume that it has sole responsibilities for all activities in the long road from the new idea for a product to its large-scale production and sale.

Product Evolution

It should be useful to those interested in planning a technique for product growth to study a model of the long and elusive process of evolution of new products. Figure 1 is one attempt to describe in a picture or model the road along which a new product travels in the various stages of its development. This model shows only part of the pattern. It attempts to describe the activities involved in the creative segment of the product evolution, the preliminary development, the development and pilot phase, and finally the production stage, but it does not list the line and functional groups who must participate and often give leadership to the continuous spiral of activities at various stages in the development.

Research Organization Planning

We have not yet reached the stage in our planning of organization and techniques for product evolution where we can suggest a

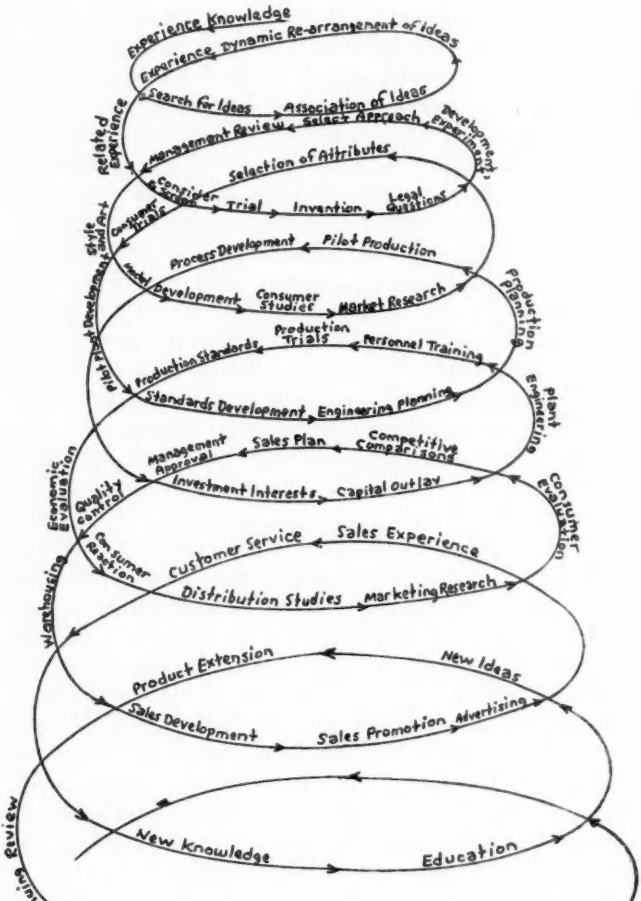

Fig. 1. A model of product evolution.

method which will fit the full range of industrial organization and product fields. Such a goal may be entirely impractical.

Those who can look back at the research director's efforts to sell the research and development function in the years following World War I can view with nostalgia the subject divisions we projected for our laboratory organization. There were chemical, physical, biological, and mechanical sections. In a later period we learned to divide the laboratory into functional divisions such as testing, library, control, development, pilot plant, and pioneering and exploratory research. These groups and combinations of subject and functional divisions can be used today to describe most modern research organizations. We should not imply in our review a criticism of these methods of dividing and classifying the parts of the R & D process. Most of us have recognized the effectiveness of the R & D function, at least to the extent of extolling it for further support and extension or, as we are doing now, subjecting it to constructive scrutiny. In retrospect, however, I doubt that we fully appreciated the strength and effectiveness of research. Had we believed in it fully, many more of us would have invested at least as little as 5% of our earnings in companies which in the 1920's were pioneering in extensive support of research activities. Such a small purchase of stock in General Electric or Du Pont for the past 30 years would have meant the building of a sizable personal fortune and would have been a solid return from one's professional involvement in research.

We have not been lax in our efforts to describe the most desirable research organization. The technical literature available is staggering. One can read a myriad of papers on techniques of management of research, organization types, and endless definitions of basic, applied, exploratory, and commercial research. There are also endless papers on personnel selection, budgeting and control, laboratory design, stimulating invention, what management wants, what the research worker wants, and how to evaluate the results. We continue to try to put a boundary of words around an elusive process. By recognizing that the system of evolution of

a new product from creation, invention, or idea through to commercialization and marketing *is* a baffling process which cannot be contained within the scope of the two words "research and development," we may see more clearly that a new technique is needed to rocket a steady stream of new products into commercial orbit.

We have been successful in our past efforts to sell research as a necessary insurance of industrial growth. Frances Bello in *Fortune*, January 1959, reports that R & D costs in the fifties will be over $60 billion and predicts that this figure will exceed $120 billion in the sixties. Such expenditures surely mean that we will find ourselves facing new scientific and technological horizons. In such an environment of change, the manager of industry must consider product growth not merely as a problem of support of research-laboratory operations but as a problem of organizing and managing the total process of product evolution pictured in Figure 1.

In 1947, Raymond P. Stevens, President of Arthur D. Little, Inc., discussed some trends in research management at a meeting of the Industrial Research Institute. He forecasts, based on industrial-research growth in the previous ten years and on the demands of the company's clients, that the research director of the future would have to become fully responsible for policy decisions in areas of *technical-economic planning*. In such areas, problems of practical *economics* become of dominant importance. Such questions as Can we do business? Can a market be created? What is the type and nature of competition? What is the policy of an industry? Can we make money? must be answered not at a late stage in a scientific and technological research program but preceding or at least paralleling the creativity and early development stages. Thus we see the beginnings of the demand that *someone* (and why not the research director?) who participates in the major policy decisions of the company should plan for new products and processes, examine markets, patents, costs, and competition and should schedule and force new product growth within his company's capital, product, and marketing potentials.

It is obvious that such a planning function cannot be conceived as the building of an empire solely within the confines of an industrial laboratory organization. Rather, it suggests the beginnings of a new function that permits the integration of various staff functions. A system must be conceived which will permit creative men with imagination and vision to *work* without frustration in concert with those having analytical and critical ability. It is the requirements of this situation, namely, the combining of the creative and critical, the imaginative and the analytical, the inventive and the practical, which lead us to consider devising a fresh approach to techniques of organization for product growth. Since we should not consider the scope of skills needed to develop a new product as *limited* to the scientific and research area, we cannot be bound by the older models of organization. In fact, it is immaterial whether our applied-research operation is divided into subject or functional departments. It *is* important that, whatever the form of the research function, it be flexible and dynamic and that, within whatever patterns exist in research, engineering, production, or sales, the product-growth effort in the form of teams or groups of individuals with scientific, human, and communicative skills can move with freedom and enthusiasm. In this concept, an existing type of line authority and responsibility for research has as its most significant feature the fact that it permits the creation of project teams which freely can break through all departmental and iron curtains.

The questions to be answered by project teams require knowledge of science and economics, of technology and law, of production and finance, and of design and markets. Such combinations of problem solvers are not consistent with a military-like "line" organization. In fact, even to conceive organized groups of project-oriented individuals with differing skills and disciplines creates havoc with some concepts of proper industrial management. It suggests potential conflicts, lack of controls, absence of leadership and incentive, and similar difficulties with the directing of skilled and individualistic personnel.

Requirements of Organization

In a review of organization patterns for effective product growth we shall here limit our thinking to the problems of the smaller and moderate-size companies. In general, these companies have little pioneering research but may be organized well for an applied-research effort with well defined product goals. It is a fortunate situation, indeed, if the specific product desired is known and the scientific and inventive process can be turned like a searchlight on known product targets. It must be recognized that the more usual situation in the average industry is one in which no one has selected or perhaps even considered what is the desire or want which must be developed into new product. If by chance certain product targets are known, authority must be assigned to buy or develop the technology which will bring the product through production and into the market.

The use of the phrase *selecting or determining what it is that is wantable* may be criticized. Some call this process creativity and define it as the ability of man to transcend conventional patterns of thought. The process of selecting or creating or breaking with conventional thought *does* involve a series of steps requiring initiative, imagination, and the ability to communicate. It is as valid an effort in developing understanding of the product-growth pattern to analyze the steps in the first stage of the process—the idea—as it is to analyze the succeeding steps of idea rearrangement, experiment, selection of attributes, and other parts of the research for new knowledge.

In discussions of creativity and how to develop a creative environment, many writers approach the problem as one in which various road blocks stand in the way of progress. Such items as authoritarianism, standardization, specialization, bigness of companies, resistance to change, traditions, desire to conform, being too practical too quickly, over-generalization, and too much faith in reason or logic are among the roadblocks to be removed. There is a concept that success breeds bigness, rigidity, smugness, and in-

adaptability and then the little people take over. This means, of course, that an organization for product growth should create an environment where conforming to a pattern is *not* a requirement, where being practical and economical does not come above all else, where it is polite to be inquisitive and to doubt everything. In such an environment one would believe that indulging in fantasy is *no waste of time* and that statistics are not always guides to proper decision. There is little doubt but that, whatever the organization set up for product growth, idea generation or creativity aimed at determining what is wantable must have its place. It is a function which must be a part of any research system no matter what form it takes.

Certain types of organization have become controversial topics in laboratory administration. The older structures consisted of groups of specialists, such as organic chemists, physicists, biologists, or electrical engineers. A problem to be solved would be routed to the group whose skills seemed to fit the problem. If several groups were required, the problem was divided into parts and so assigned. In other variations of this pattern, the work was divided between groups concerned primarily with long-range research of the exploratory type and those called development groups concerned with shorter-range efforts. Library, testing facilities, pilot-plant, and patents became service divisions of research and development. It is an oversimplification to classify this type of organization as functional, since it frequently may operate on a project basis made popular by aircraft development and dramatized by the Manhattan Project and our various rocket and space-probe efforts.

This project type of approach in its pure form assumes that when a project enters the laboratory a group which includes all of the necessary skills is organized to solve the problem. The group disbands when the problem is solved.

If problems are small, project groups are unnecessary; if long and complex, the project group may become almost continuous. It is my belief that most industrial laboratories have a size of prob-

lems and responsibilities for commercial development associated with them that requires that a much greater emphasis be placed on the project-team technique.

Actually, if we were to approach the question of organizing for a specific problem of product growth with no preconceived notions of scientific disciplines, specialties, or stages of research or development effort, we might turn naturally to the most primitive form of joint effort—a team or group organized especially to solve the problem. Such a group has definite advantages. Its leadership is specific and selected because of known assets. The skills included in the group would be based on recognition of the broad scope of the problem at its earliest stages. The priority of the effort would be known. Responsibility and authority would have been clarified. No curtains of command or prestige would have been created. The rebirth of a new field of authority for the solution of a problem usually suggests self-generating enthusiasm and creative motivation. It is easy to introduce youth into such a picture since others in the group may have age and experience.

The method of bringing scientists, engineers, economists, market analysts, lawyers, and persons from other disciplines into a group having a limited objective has had some startling success in developments in microwave communication, synthetic rubber, and of course, atomic energy. As a result, the project system, particularly as a way of carrying out developmental research, has won many proponents among those who formerly believed in individualism in research. Many have found the project-team method one which permits a more concise assessment of project costs and consequently one which permits a more intelligent tie-in with a commercial development appraisal. The project team is less vulnerable to a dispersion of its development effort since it is not so fair a target for demands of technical and sales service as are development groups with existing process titles such as Chemical Process Development.

While many feel that the project system is necessary for faster progress in the consummation of research ventures, no one is

predicting that this method should become the only technique used by industry. It is appreciated by all that the laboratory, to assist in forming new ideas and translating them into action, must be flexible in structure. Thus the goal may well be the organization which provides the values of the project system but allows freedom in the general search for knowledge where specific goals have not been identified.

The project-team method is used in the research and development services of Arthur D. Little, Inc. to its clients. No other method is feasible in this case, since a client's problem may be identified with any stage of industrial effort from a need for help in applying the scientific laws of energy or matter to help with the methods of marketing or the evaluation of response to advertising. The key to a successful project team is of course its head or leader. He must have identified himself with knowledge of the problem, some ideas of possible approaches, and faith in a solution. He must seek help from associates in planning the effort, outlining the areas of critical skill, selecting the project team personnel, and programming the follow-up and evaluation during the development effort. He must coordinate the findings and present conclusions and recommendations. There is little question but that the technique has wide application to the problems presented to industrial laboratories and should be used at an increasing rate. It is a method of solving problems of development and product growth which deserves more active support by management, since it may also help solve the problem of maintaining a climate of youthfulness and challenge in the company's executive and supervisory as well as its research staff.

The basic requirement for new-product growth is, of course, originality and creativity in the R & D group but there is evidence that maturity and size of organization develop inertia and rigidity and finally degeneration. Dr. W. Lothrop suggests that liaison between top management and research and development is basically a problem involving time and geriatrics: of maintaining a balance between the assets of youth and the judgments of maturity.

There is little doubt that maintaining youthful creativity and enthusiasm is the major problem in product-growth programs.

Lewis Carroll raised a pertinent question which Lothrop revised slightly:

> "'You are old, R & D,' the young man said,
> "'And your hair has become very white,
> And yet you incessently stand on your head—
> Do you think, at your age, it is right?'"

Lothrop answered with emphasis—"*Yes.*"

Research and Development as a Management Function

There is a phase of the methodology for corporate product growth which has been given little attention. While it is recognized that management's interest in product growth should be continuous and should be translated into an insurance policy in the form of a reasonable research effort, there has been little recognition of the fact that the operations and demands of business do not permit or even encourage top-management participation in problems of project selection. Many research personnel complain bitterly of their failure to obtain even a modest amount of the time of top management for consideration of and decision on vital new-product questions. A staff-committee system of evaluation has been developed by many research directors as a technique for forcing the chief executive officers of production, marketing, and finance into brief periods of consideration, evaluation and approval of development and commercialization programs. All too often, other duties force postponement of meetings, and the progress of projects carried forward under the functional system in R & D is delayed and even stopped by pure inertia. For this dilemma, the project-team technique offers an interesting and hopeful solution. Placing responsibility on a project director and on a team organized to include most of the areas of corporate skill which should be involved in decision and action in itself creates a dynamic force not likely to be halted by failure to involve executive partic-

ipation. As a matter of fact, the team includes, through its membership representative of broad corporate interests, the necessary elements for decisive action. It can replace the older patterns of authority in which the manager makes the decisions and announces them. The project-team approach allows the development of new areas of freedom for research and development and for junior management personnel. It permits them to function even if top management does not know what the problem is. The project-team approach sets up limits or criteria for the responsibility and authority of the development personnel and allows decisions and progress to be made without the delays associated with older organization forms.

Summary

In the discussion of the problem of stimulating the creation and introduction of new products, we have presented an analysis of a complex path of product evolution. The complexity of the path and the number of areas of information and action suggests that we should revise some concepts of the part the research laboratory plays in a product-growth program. The change suggested is that specific problems of product growth be assigned to project teams. These teams or groups must include personnel capable of easily crossing the usual department lines and independent of control by the usual laboratory operating divisions. A project-team technique properly directed will break down iron curtains between the R & D organization and executive participation in the research effort. It also suggests the need for a manager of corporate development to represent the technology of the company and having responsibility for continuous programs of product growth.

We have suggested that the existence and life of a company is dependent on the rate at which it succeeds in product growth. Without a dynamic program with responsibility, techniques, and authority assigned, a company may suddenly find itself fighting for its existence in competition with intriguing new technologies developing in unexpected quarters.

Managers of industry should seek methods to avoid the problems of communication troubling the dachshund in the rhyme:

> There was a dachshund once so long
> He hadn't any notion
> How long it took to notify
> His *tail* of his emotion.
> And so it was that while his eyes
> Were filled with tears and sadness
> His little tail kept wagging on
> Because of previous gladness.

To avoid surprises in the technological progress of the next decade, management should project a new concept of mechanisms for the development of corporate growth through a revision of the relationship between management and the research and development function. The project-team effort appears to offer the greatest hope of a method of correlating the functions of research, design, patent law, engineering, market research, production, and marketing. The project-team method seems to be intimately linked with a new and better model of the scientific approach to problem solving.